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**EVALUATION PROGRAM**  
**for**  
**SECONDARY SPACECRAFT CELLS**

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ACCEPTANCE TEST  
OF  
GENERAL ELECTRIC COMPANY  
5.0 AMPERE-HOUR NIMBUS CELLS

prepared for  
GODDARD SPACE FLIGHT CENTER

CONTRACT W11,252B



QUALITY EVALUATION LABORATORY  
NAD CRANE, INDIANA

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UNITED STATES NAVAL AMMUNITION DEPOT  
CRANE, INDIANA

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QE/C 65-459

23 June 1965

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Enclosure (1)

## REPORT BRIEF

## GENERAL ELECTRIC FIVE AMPERE-HOUR NIMBUS NICKEL CADMIUM

## SECONDARY SPACECRAFT CELLS

- Ref: (a) National Aeronautics and Space Administration Purchase Order Number W11,252B  
(b) NASA ltr BRA/VBK/pad of 25 September 1961 w/BUWEPS first end FQ-1:WSK of 2 October 1961 to CO NAD Crane  
(c) Preliminary Work Statement for Battery Evaluation Program of 25 August 1961

I. TEST ASSIGNMENT BRIEF.

A. In compliance with references (a) and (b), evaluation of General Electric Company five ampere-hour nickel cadmium Nimbus Secondary Spacecraft Cells was begun according to the program outline of reference (c).

B. The object of this evaluation program is to gather specific information concerning secondary spacecraft cells. Information concerning performance characteristics and limitations, including cycle life under various electrical and environmental conditions, will be of interest to power systems designers and users. Cell weaknesses, including cause of failure of present designs, will be of interest to suppliers as a guide to product improvement.

C. Thirty cells were purchased from General Electric Company, Gainesville, Florida by National Aeronautics and Space Administration (NASA). These cells are rated at five ampere-hours by the manufacturer and are similar to those used in the Nimbus satellite program.

II. CONCLUSIONS.

A. From the results of this test, it can be concluded that:

1. The ceramic seals of these cells manufactured by General Electric Company are satisfactory as evidenced by no leakers out of the 30 cells tested.

2. The capacity of the cells was in the acceptable range of 5.13 to 7.08 ampere-hours to 1.00 volt.

III. RECOMMENDATIONS.

A. It is recommended that these General Electric Company five ampere-hour Nimbus cells be accepted on the basis of the acceptance test results.

RESULTS OF ACCEPTANCE TESTS  
OF  
FIVE AMPERE-HOUR NIMBUS NICKEL CADMIUM SECONDARY SPACECRAFT CELLS  
MANUFACTURED BY  
GENERAL ELECTRIC COMPANY

I. INTRODUCTION.

A. On 4 March 1965, this activity began acceptance tests on 30 cells. These tests were completed on 16 April 1965.

II. TEST CONDITIONS.

A. All acceptance tests were performed at an ambient temperature between 23° C and 27° C at existing relative humidity and atmospheric pressure, and consisted of the following:

1. Phenolphthalein Leak Test.
2. Conditioning Cycle.
3. Capacity Test.
4. Cell Short Test.
5. Immersion Seal Test.
6. Overcharge Test.
7. Internal Resistance Test.
8. Immersion Seal Test.

B. All charging and discharging was done at constant current ( $\pm 5$  percent). Cells were charged in series but discharged individually.

III. CELL IDENTIFICATION AND DESCRIPTION.

A. The cells were identified by the manufacturer's serial numbers which were from 1-14 to 3-198, although not consecutively.

B. The five ampere-hour Nimbus cell is cylindrical in shape with a convex base. A threaded stud is fastened to the base to facilitate heat sink mounting. The cell has an average length (base, excluding the threaded stud, to top of the container) of 3.362 inches and

average diameter of 1.278 inches. The average weight was 197.4 grams. Figure 1 is a photograph of a General Electric Company five ampere-hour Nimbus cell.

C. The cell container or can, and the cell cover are made of stainless steel. Two stainless steel tabs, welded to the cover, serve as the contacts for the negative terminal. The positive terminal is insulated from the cell cover by a ceramic bushing and protrudes through the bushing with a solder tab welded to the terminal.

D. These cells, rated by the manufacturer at five ampere-hours, were received in a partially discharged condition.

#### IV. TEST PROCEDURE AND RESULTS.

##### A. Phenolphthalein Leak Test:

1. The phenolphthalein leak test is a determination of the condition of the welds and ceramic seal on receipt of the cells. The test was performed prior to any other tests using a phenolphthalein spray indicator solution of one-half of one percent concentration.

2. There were no signs of leakage on any of the 30 cells subjected to the leak test.

##### B. Capacity Test:

1. Prior to the capacity tests, the cells were given a preconditioning cycle. This cycle consisted of a 48-hour charge at 250 milliamperes followed by a 2.5 ampere discharge to a cutoff of 1.00 volt per cell and then shorted out through a 1-ohm resistor for 16 hours.

2. The capacity test is a determination of the cell capacity at the  $c/2$  discharge rate, where  $c$  is the manufacturer's rated capacity, to a cutoff voltage of 1.00 volt per cell. Because of instrumentation requirements on the Nimbus satellite, capacities were measured to 1.15 volts per cell in addition to the 1.00 volt cutoff. The discharge was made after a 1-hour open circuit period following the 16-hour charge at the  $c/10$  rate. A total of three capacity checks were made at this activity. The cells were discharged individually, but were recharged in series.

3. Since no capacity data was submitted by the manufacturer, it was not possible to compare the manufacturer's capacity values with those of this activity. The individual cell capacities ranged from 4.93 to 6.30 ampere-hours for an average of 5.57 ampere-hours to 1.15 volts and from 5.13 to 7.08 ampere-hours for an average of 5.78 ampere-hours to 1.00 volt. The cell capacities are tabulated in Table I. Characteristic 2-hour rate discharge curves are shown in Figure 2.

### C. Cell Short Test:

1. The cell short test is a means of detecting slight shorting conditions which may exist because of imperfections in the insulating materials, or damage to element in handling or assembly.

2. Following completion of the third capacity discharge test, each individual cell was loaded with a resistor of value giving a c/1 to c/5 discharge rate and allowed to stand 16 hours with the resistor acting as a shorting device. At the end of 16 hours, the resistors were removed and the cells were placed on open circuit stand for 24 hours. Any cell whose voltage did not recover to 1.15 volts or higher was rejected.

3. The open circuit cell voltages, 24 hours after removal of the shorting resistors, ranged from 1.18 to 1.21 volts for an average of 1.19 volts.

4. There were no rejects of any of the cells subjected to the cell short test. The voltage values for the 30 accepted cells are shown in Table I.

### D. Immersion Seal Test:

1. The immersion seal test is a means of detecting leakage of a seal or weld. The test was performed before and after the overcharge test sequence to determine the presence and cause of leaks.

2. The cells were placed under water in a bell jar container. A vacuum of 20 inches of mercury was held for 3 minutes. Cells discharging a steady stream of bubbles were considered rejects.

3. There were no rejects in the 30 cells subjected to the immersion seal test.

### E. Overcharge Test:

1. The overcharge tests were performed to determine the steady state voltage at specified rates. The test specified a series of constant current charges at c/20, c/10 and c/5 rates, for a minimum of 48 hours at each charge rate or until the increase of the "on-charge" voltage was less than 10 millivolts per day.

2. The cells were monitored hourly throughout the test. Charging was to be discontinued on cells which exceeded 1.50 volts while on charge. There was no need to remove any cells from the charging sequence.

3. The steady state voltage of each cell at the end of each 48-hour charge rate test is shown in Table I. Characteristic overcharge voltage curves are shown in Figure 3.

F. Internal Resistance Test:

1. This test was performed to determine the internal resistance of the cell.

2. At the completion of the overcharge test; the cells were returned to the c/20 charging rate and given a short pulse (5-10 seconds) at the rate of c in amperes. The cell voltages, V1, immediately prior to the pulse; and V2, 5 milliseconds after the pulse, were read on a suitable recording instrument. A CEC high speed oscillograph recorder (28.8 inches of tape per second) was used. The internal resistance of the cell in ohms was calculated according to the following formula:

$$R = \frac{V2 - V1}{Ic - Ic/20}$$

V1 and V2 are in volts, Ic and Ic/20 are in amperes.

3. The internal resistance value for each cell is shown in Table I. The values range from 2.10 milliohms to 8.42 milliohms.

TABLE I

CELL NUMBER	DIAMETER (INCHES)	HEIGHT (INCHES)	WEIGHT (GRAMS)	CAPACITY TEST (1) (2)	CAPACITY TEST (1) (2)	CAPACITY TEST (1) (2)	CELL SHORT TEST	IMMERSION SEAL TEST LEAKAGE	OVER- CHARGE c/20	OVER- CHARGE c/10	OVER- CHARGE c/5	INTERNAL RESISTANCE (MILLIOHMS)	IMMERSION SEAL TEST LEAKAGE
1-14	1.277	3.357	196.9	5.45 5.50	5.20 5.33	5.05 5.18	1.21	NONE	1.39	1.43	1.43	4.21	NONE
1-17	1.277	3.360	197.3	5.58 5.70	5.33 5.50	5.18 5.43	1.20	NONE	1.40	1.44	1.45	2.10	NONE
1-20	1.279	3.357	195.4	5.63 5.75	5.43 5.58	5.20 5.45	1.20	NONE	1.40	1.44	1.45	4.21	NONE
1-29	1.280	3.365	197.6	5.70 5.88	5.43 5.70	5.18 5.55	1.20	NONE	1.40	1.47	1.50	8.42	NONE
1-35	1.280	3.367	198.2	5.55 5.68	5.38 5.50	5.18 5.43	1.20	NONE	1.40	1.45	1.45	4.21	NONE
1-36	1.278	3.365	197.3	5.55 5.75	5.25 5.55	5.13 5.43	1.20	NONE	1.40	1.45	1.45	8.42	NONE
1-38	1.275	3.358	194.7	5.45 5.68	5.20 5.38	5.00 5.25	1.20	NONE	1.40	1.44	1.44	8.42	NONE
1-40	1.276	3.363	198.3	6.08 6.20	5.83 6.08	6.30 7.08	1.19	NONE	1.40	1.45	1.45	4.21	NONE
1-41	1.275	3.360	197.2	6.18 6.30	6.05 6.20	5.70 6.05	1.19	NONE	1.40	1.45	1.46	4.21	NONE
1-42	1.277	3.360	197.5	6.05 6.18	5.80 6.00	5.55 5.88	1.20	NONE	1.40	1.45	1.47	6.31	NONE
1-43	1.278	3.367	199.2	5.68 5.83	5.43 5.68	5.08 5.55	1.20	NONE	1.40	1.45	1.46	8.42	NONE
1-44	1.277	3.370	196.3	5.18 5.30	4.88 5.08	4.75 5.00	1.21	NONE	1.39	1.43	1.44	6.31	NONE
1-55	1.279	3.370	198.2	6.13 6.18	5.63 5.95	5.55 5.80	1.18	NONE	1.40	1.45	1.45	6.31	NONE
1-80	1.277	3.365	198.7	5.68 5.80	5.33 5.58	5.08 5.43	1.18	NONE	1.40	1.45	1.46	6.31	NONE
1-81	1.279	3.368	197.5	5.63 5.75	5.33 5.58	5.43 5.58	1.18	NONE	1.40	1.45	1.46	6.31	NONE

Capacity Test (1): To 1.15 Volts.  
Capacity Test (2): To 1.00 Volt.



TABLE I (Contd)

CELL NUMBER	DIAMETER (INCHES)	HEIGHT (INCHES)	WEIGHT (GRAMS)	CAPACITY TEST		CAPACITY TEST		CAPACITY TEST		CELL SHORT TEST	IMMERSION SEAL TEST LEAKAGE	OVER- CHARGE c/20	OVER- CHARGE c/10	OVER- CHARGE c/5	INTERNAL RESISTANCE (MILLIOHMS)	IMMERSION SEAL TEST LEAKAGE
1-87	1.280	3.368	199.3	5.55	5.63	5.45	5.63	5.33	5.50	1.18	NONE	1.43	1.44	1.44	6.31	NONE
1-89	1.280	3.350	196.7	5.63	5.75	5.43	5.68	5.25	5.50	1.18	NONE	1.43	1.44	1.43	6.31	NONE
1-91	1.279	3.348	198.2	5.75	5.95	5.63	5.93	5.50	5.75	1.18	NONE	1.43	1.44	1.44	8.42	NONE
1-98	1.276	3.355	197.6	5.63	5.93	5.50	5.83	5.30	5.68	1.18	NONE	1.43	1.44	1.44	6.31	NONE
*1-156	1.280	3.375	346.2	5.68	5.88	5.58	5.83	5.38	5.63	1.19	NONE	1.42	1.42	1.42	6.31	NONE
*1-157	1.284	3.360	343.5	5.43	5.63	5.33	5.50	5.08	5.33	1.18	NONE	1.42	1.42	1.42	4.21	NONE
*1-158	1.276	3.363	344.9	5.63	5.88	5.55	5.83	5.33	5.63	1.18	NONE	1.42	1.43	1.43	4.21	NONE
2-170	1.276	3.360	198.3	5.20	5.43	5.00	5.33	4.80	5.13	1.18	NONE	1.43	1.44	1.44	4.21	NONE
2-171	1.275	3.365	198.1	5.18	5.55	4.88	5.20	4.63	4.93	1.19	NONE	1.43	1.44	1.44	8.42	NONE
2-175	1.280	3.360	191.3	4.93	5.25	4.68	5.08	4.45	4.93	1.18	NONE	1.44	1.44	1.44	6.31	NONE
2-180	1.276	3.372	197.3	4.93	5.13	4.58	4.93	4.25	4.45	1.19	NONE	1.43	1.44	1.44	6.31	NONE
3-194	1.276	3.372	199.5	5.58	5.80	5.33	5.63	5.13	5.45	1.18	NONE	1.43	1.44	1.44	6.31	NONE
3-195	1.280	3.368	196.2	5.43	5.80	5.20	5.63	5.00	5.45	1.18	NONE	1.43	1.44	1.45	8.42	NONE
3-196	1.276	3.352	199.3	5.55	5.83	5.43	5.70	5.18	5.55	1.18	NONE	1.43	1.44	1.45	6.31	NONE
3-198	1.275	3.352	196.4	5.30	5.63	5.08	5.50	4.88	5.33	1.18	NONE	1.44	1.44	1.45	6.31	NONE

\* Pressure Transducers

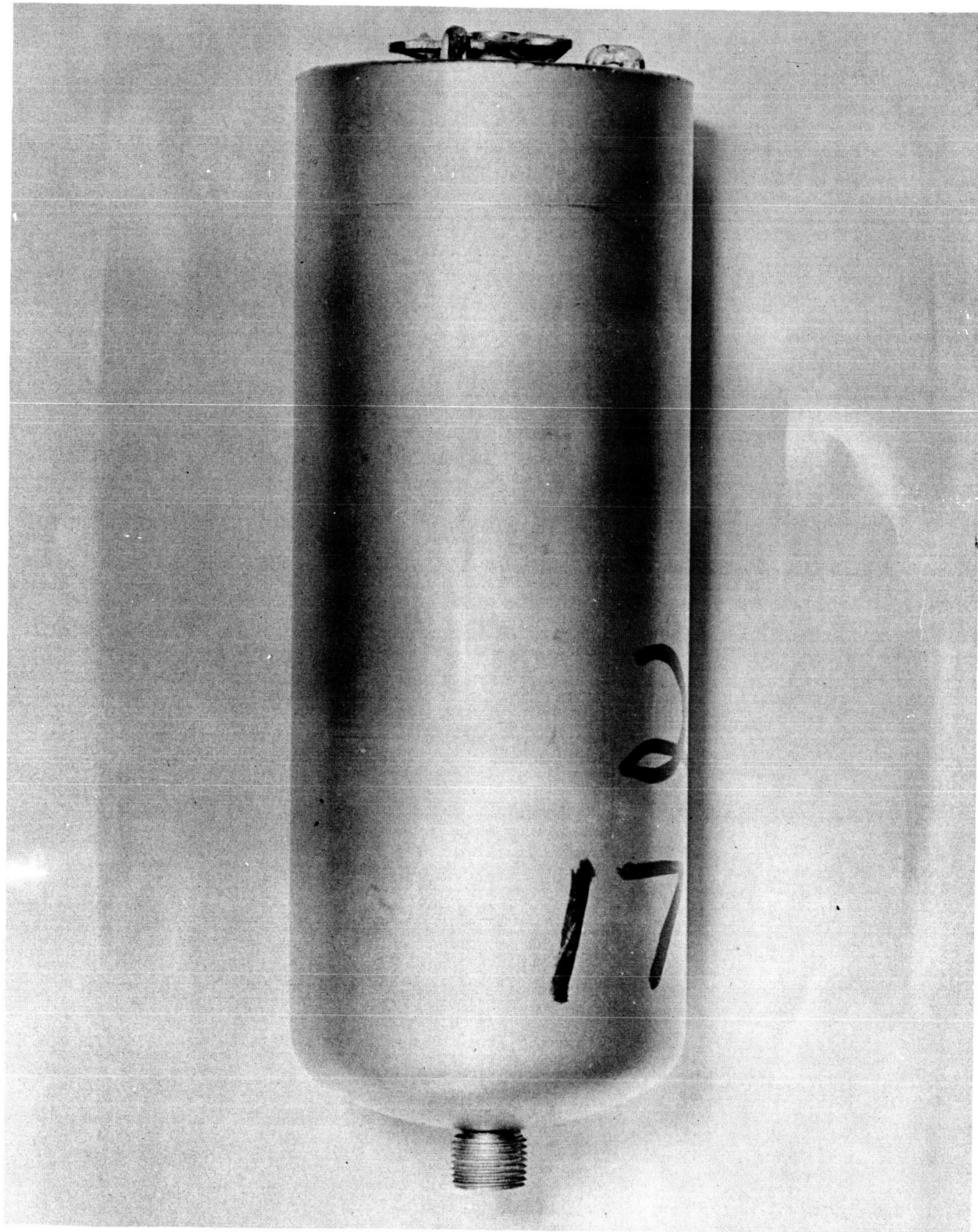
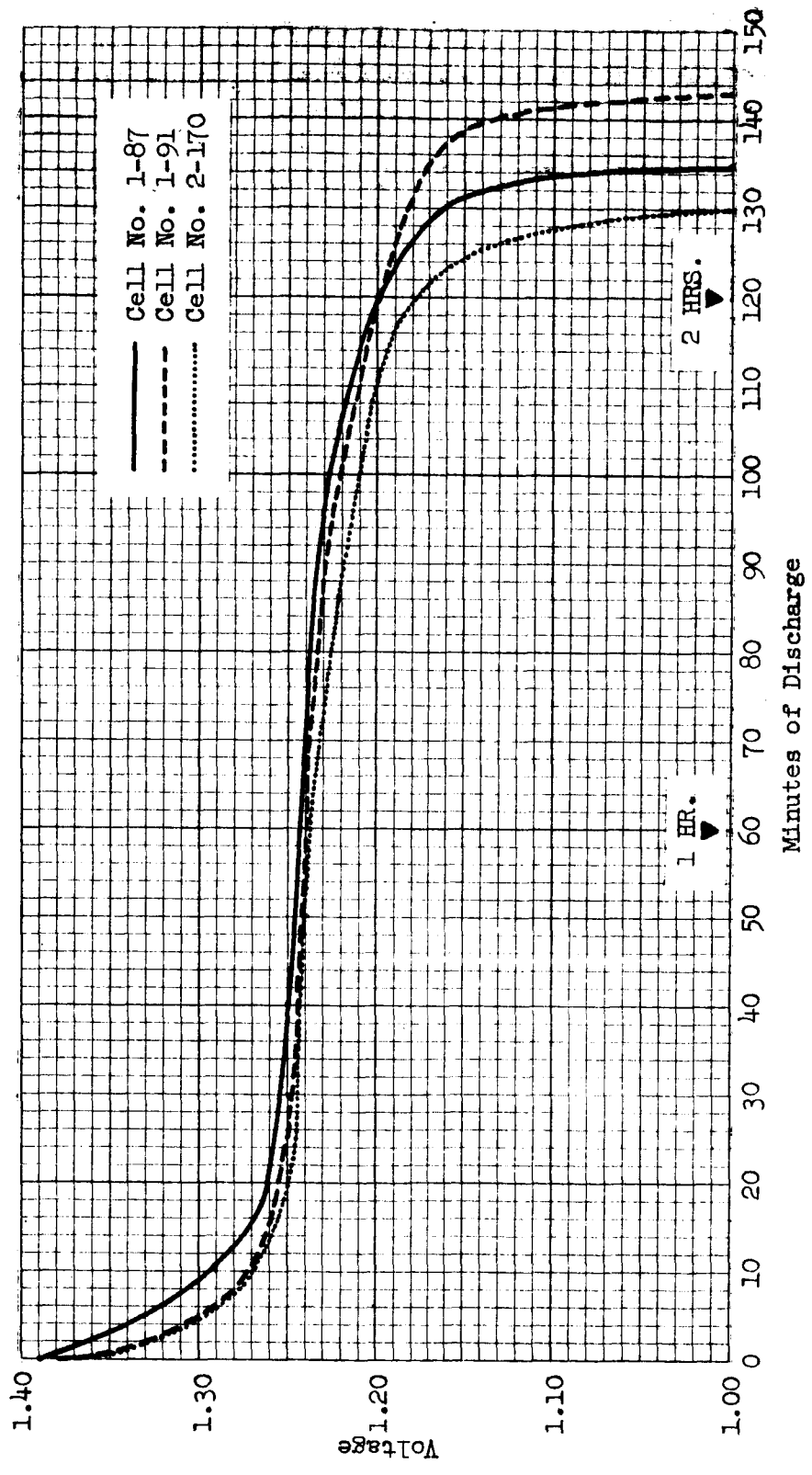


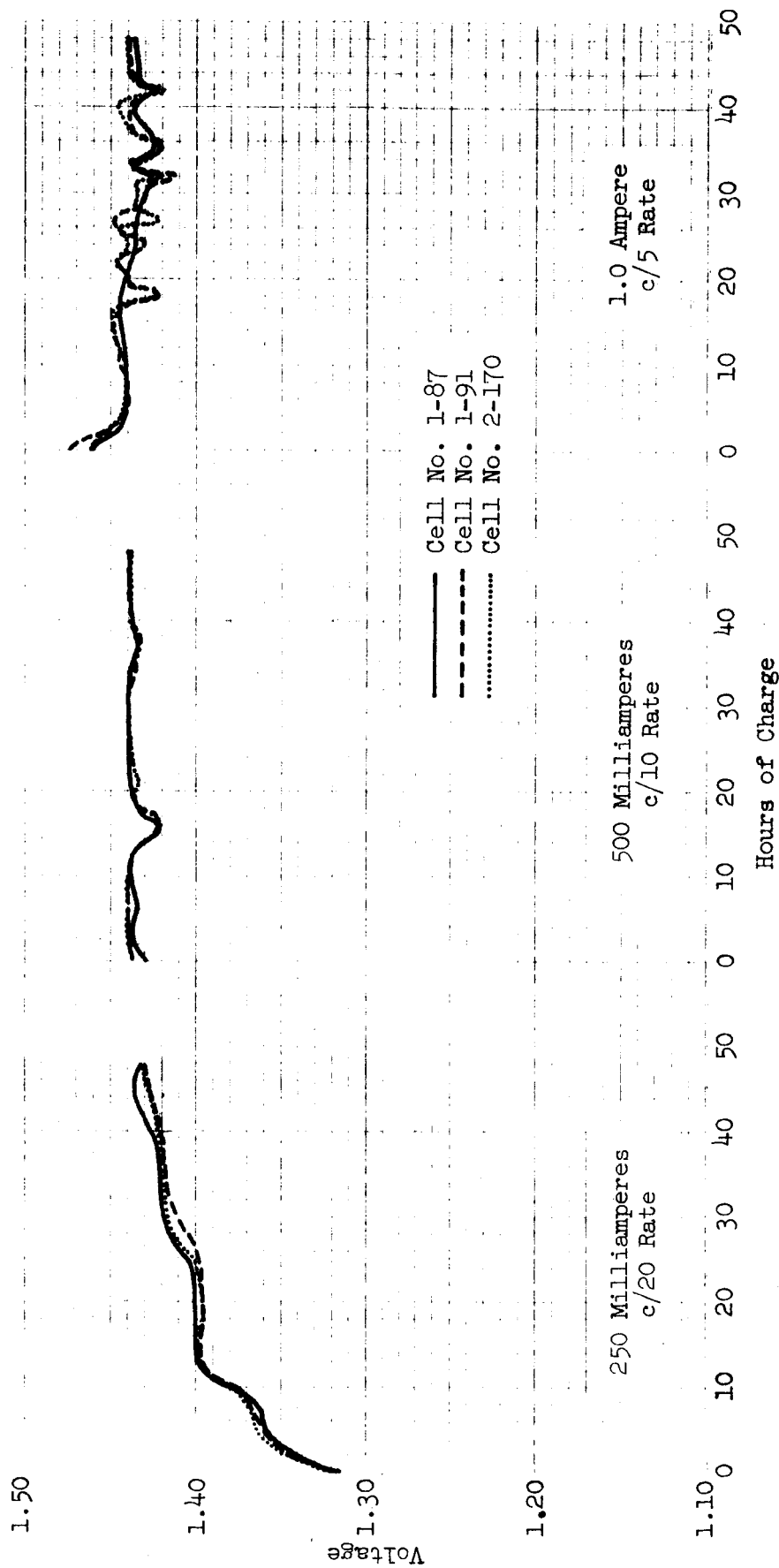
FIGURE 1



CHARACTERISTIC 2-HOUR RATE DISCHARGE CURVES

GENERAL ELECTRIC 5 AMPERE-HOUR NIMBUS NICKEL CADMIUM SEALED CELLS

FIGURE 2



CHARACTERISTIC 48-HOUR OVERCHARGE CURVES

GENERAL ELECTRIC 5 AMPERE-HOUR NIMBUS NICKEL CADMIUM SEALED CEL

FIGURE 3

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